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ABSTRACT
Vegetation phenology describes the plant life cycle or activity and it is important to understand it's interactions with climate. This study is conducted to identify plant phenological responses to average monthly rainfall and to extract the phenology metrics for oil palms trees by using EVI vegetation indices from MODIS-Aqua (product MYD13Q1) from year 2000 to 2014. This is an ongoing project and an initial test result based on a subset of data in 2007 and 2009 is reported. Year 2007 receives normal rainfall while 2009 experiencing less rains in eleven years (2000-2010). The initial test results show that the phenological trends of oil palms fluctuate in 2007 compared to 2009 with EVI at 0.45-0.71 and 0.5-0.74 respectively. Effect of time-lag period on vegetations' greenness was detected, especially after heavy rain period in both years which affects the correlation values between the average rainfall and EVI. There is no major difference between the lengths of growing season in both year, which is 32 days longer in 2007 compared to 2009. A longer term dataset will provide a better understanding of the climate change effects on the phenological response of oil palm which will inevitably impacting the socio-economic aspects of oil palm growers.

Keywords: Vegetation phenology, MODIS, EVI, phenological matric, growing season.

Introduction

The vegetation phenology is an expression of seasonal cycles of plants which contributes important information regarding the current state of the plant and its relation to climate change (Farooq 2012). The phenology dynamics of terrestrial ecosystems reflects the inherent reaction between the biosphere and the dynamism of the earth's climate (Zhang et al. 2003; Menzel et al. 2006), and is important in understanding the interactions between the biosphere and the climate and its impact in space and at different scales (Yu et al. 2014). The vegetation's growing process, reproduction and survival in a vegetation cycle is dependent on environmental conditions experienced by plants (Sykes 2009). Research showed that the plant phenology cycle and its tolerance of the environment differ according to the species of plants (Qifei Han 2012). With the availability and accessibility to satellite data, vegetation phenological research using high temporal resolution satellite sensors is gaining momentum. A number of remote sensing approaches have been tested and successfully applied in the study of changes in the composition, vegetation cover and structure. Satellite sensors such as the Advanced Very High Resolution Radiometer (AVHRR), Moderate Resolution Imaging Spectroradiometer (MODIS), Medium Resolution Imaging Spectrometer (MERIS) and Satellite Pour l'Observation de la Terre Vegetation (SPOT VEGETATION) capture images of the earth's surface at moderate spatial resolution but at high temporal resolution (Senf et al. 2013) and are often used to investigate the vegetation pheno-phases. Changes in vegetation can be analyzed using time series remote sensing data such as Normalised Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI).

In Malaysia, the application of remote sensing technology in vegetation phenology study is still lacking behind. Field observation and records of changes in vegetation growing season at plot scale limits the study to a small area compared to the use of remote sensing technology which covers up to global scales. The use of remote sensing approach in the humid tropic regions faced with challenges from the constantly high clouds cover and aerosol content in the atmosphere. These factors affect the temporal analysis of remote sensing data and is one of the reason why the plant phenology in the humid tropics is poorly documented (Moreau & Defourny 2012). Moreover most researchers pay less attention to the fact that the plant phenology is not only responsive to temperature but also responsive to the precipitation. Malaysia receives high rainfall throughout the year but distribution and seasonal variations exist, resulting in years with less rainfall (Sharifah Haslinda 2011). With climate change issues became topic of hot discussion in the field of plant phenology, there is an urgent need to assess climate change impact on local vegetation. Therefore, the main goal of this study is to identify intra-annual and inter-annual changes in oil palm phenology for 2007 and 2009 using MODIS data. In addition, the plant phenological response to the average monthly rainfall is studied to understand the intra-annual response to the presence of water and to detect long-term changes in the vegetation.

Study area

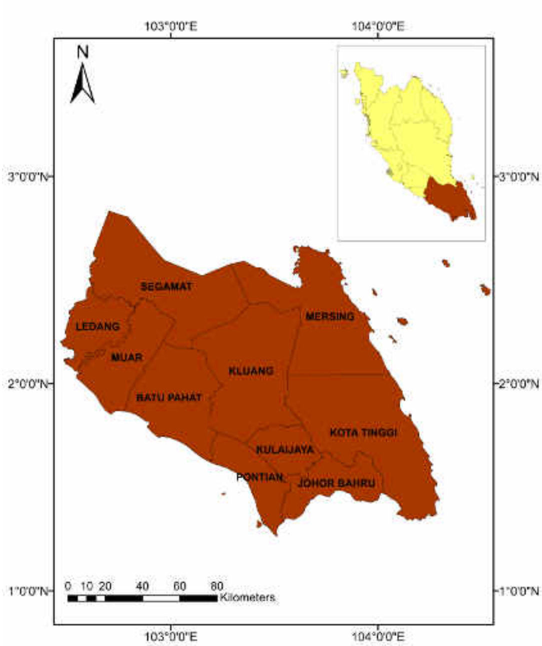


Figure 1 Study area

The state of Johore is located at the southern part of Peninsular Malaysia between longitude 102° 29’ 22” and 104° 30’ 47” E and latitude 1° 20’ 25” and 2° 49’ 42” N (Figure 1) covering a total area of about 19,016 km^2 . Johore has tropical climate with mean annual temperature of 27 °C and mean annual precipitation of 2600 mm. Large areas of Johor consists of plains and low undulating topography of less than 200 m. The northern and central part of Johore is characterised by hilly topography with an altitude of about 180 m to 600 m and exceeding 600 m on the eastern part. As of 2012, more than half the area in Johore was covered by agricultural land use (59.1 %), followed by forest (28.7 %) (Town and Country Planning Department of Peninsular Malaysia).

DATA AND METHODS

Data

The MODIS Aqua (MYD13Q1) Enhance Vegetation Indices (EVI) with 250 m spatial resolution and 16 days temporal resolution was used in this study. A total of 46 MYD13Q1 product data (23 data per year) for 2007 and 2009 have been obtained from the United States Geological Survey (USGS). EVI was developed to optimize the reflectance signal from vegetation and to correct the distortions caused by the reflection of light by atmospheric particles and the effect of the reflection of soil background under the plants. EVI data does not saturate easily compared to NDVI (Tan et al. 2008), especially in rainforest areas and in areas of high biomass content. In addition, the average monthly rainfall data of Johore (2000-2010) was obtained from the Meteorological Department of Malaysia. Over the period of 11 years, two set of data were identified and selected for analysis consisting of a year with normal rainfall (2007) and a year with lesser rainfall (2009).

Image pre-processing

EVI data was extracted from the MODIS Aqua dataset product MYD13Q1 and subjected to some image pre-processing steps such as data quality inspection, geometric transformations from the Sinusoidal projection to GDM 2000 MRSO Peninsular Malaysia projections, image clipping and format conversion. Majority of the image pre-processing steps were done via the Model Builder in ArcGIS 10.3 software.

Identifying and Extracting Oil Palm Plant Phenology

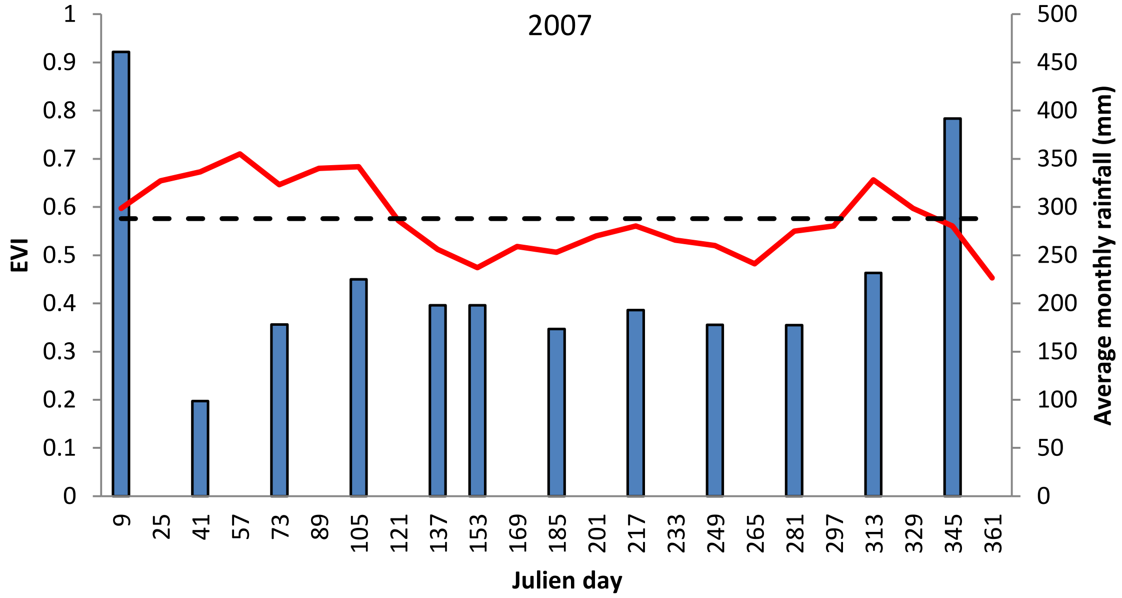
The oil palm plant was identified through visual interpretation of Landsat TM images acquired in 2007 and 2009 using a combination of false-color composite image bands 4,5,3. The identified locations of oil palm plant were verified through the Google Earth application. Seasonal and phenological metric curve (start of the season, the end of season and the length of the growing season) for the oil palm were extracted and analysed using Timesat software (Jönsson & Eklundh 2004). Savitzky-Golay filtering method was applied for smoothing the raw EVI data.

Analysis of the Relationship between EVI and monthly rainfall

The Pearson correlation analysis method was applied to investigate the relationship between the average monthly rainfall and EVI values of oil palm vegetation in both years.

RESULT AND DISCUSSION

Oil palm can live with a minimum average monthly rainfall of 150 to 420 mm provided that the soil is well drained (Ariffin et al. 2001). The production and harvest of oil palm fruit is expected to increase when there is enough rain and decrease during prolonged dry period (Ariffin et al. 2001; Cadena et al. 2006). In the west coast of Sabah, Puah and Madihah Jaafar Sidek (2011) found that high rainfall and temperatures provide favourable conditions for the production of oil palm fruit. However, if the amount of rainfall causes flooding then it will led to the mortality of the palm trees. This shows that oil palm is responsive to the amount of rainfall received but not to the extent of too extreme or too limited which will affect its growth cycle.



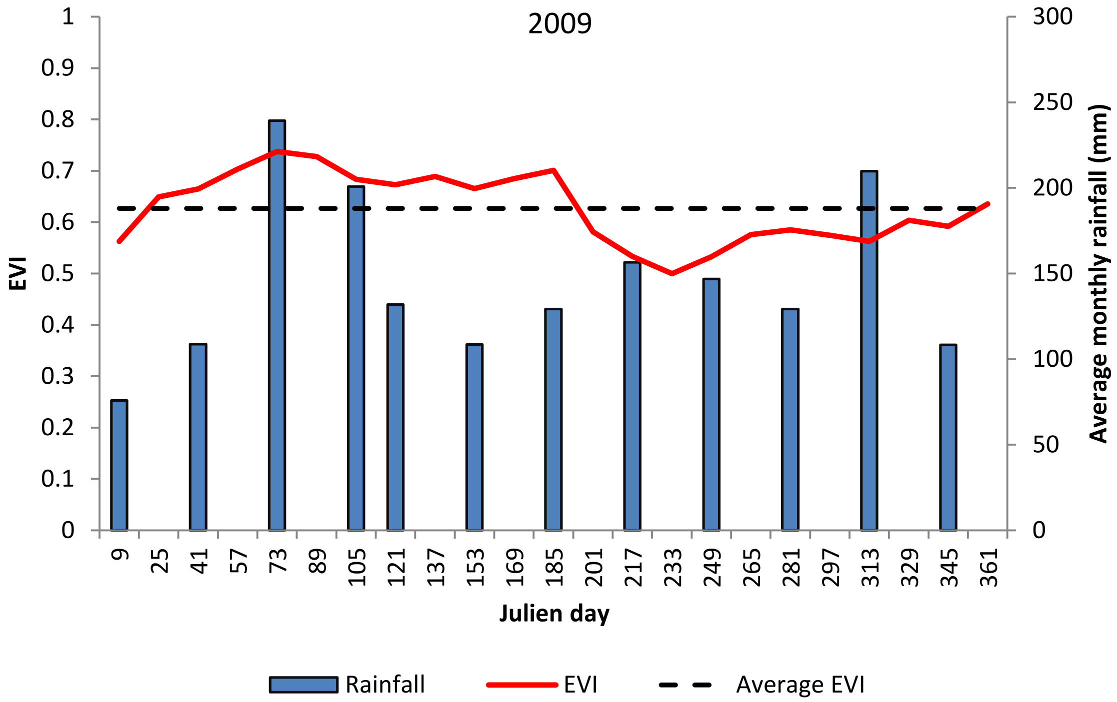


Figure 2 The trend of oil palm phenology and average monthly rainfall for 2007 and 2009.

Figure 2 shows the EVI values for palm oil in both years with an average of 0.58 in 2007 and 0.63 in 2009. Even though there were months in 2009 that receives average monthly rainfall of less than 150 mm, the average EVI was higher in 2009 compared to 2007 which has only one month (February) that received less rainfall. This shows that the EVI of oil palm maintains a higher level during the period of receiving monthly rainfall exceeding 100 mm and the length of the dry season (with rainfall <100 mm) not exceeding two months (Muhammad Rizal & Tsan 2008; Ramli Abdullah & Mohd Basri Wahid 2011). It is assumed that the EVI is still at a high level and the negative correlation ($r = -0.083$) in 2007 is due to the time-lag effects from high rainfall in the preceding months. High average monthly rainfall in December 2006 (603.4 mm) and January 2007 (460.9 mm) causes the EVI to remains consistent for a period of approximately four months (January to April) although the average precipitation in February decreased by 362.1 mm compared to the previous month.

The EVI for January 2009 was comparatively higher even though the amount of rainfall for that month at 75.9 mm was the lowest throughout 2009. This may be explained by the amount of rainfall at 207.8 mm received in December 2008, which provide enough moisture for the next two months (January and February 2009). The highest rainfall was recorded in March 2009 (239.3 mm) and consistently high for the next month (200.8 mm) which keeps the EVI values consistent for the following two months. The time-lag effect was also detected towards the end of December where EVI value rises above the average, a month after a relatively high rainfall recorded in November (Figure 2). Puah and Madihah Jaafar Sidek (2011) found that time-lag period of up to three months was detected from 2005 to

2010 in the west coast of Sabah and concludes that the production of oil palm bunches were strongly associated with rain.

The correlation analysis results are not significant and very weak between the EVI and average monthly rainfall in 2007 (r = -0.083) and 2009 (r = 0.137). The non-significant correlation results in both years shows that there are low confidence to confirm that the relationship between EVI and average monthly rainfall in both years have a weak relationship. It is presumed that time-lag effect could be one of the factors which affects the variations of EVI based on the low r^2 values in both years at 0.01 (2007) and 0.02 (2009) respectively.

In Tumaco, southwestern of Columbia, Cadena et al. (2006) found that the response of oil palm plants to rainfall has a time-lag of three months which affects the greening up of the oil palm vegetation. The lag period is one of the presumed major factor affecting oil palm's EVI variations other than the average monthly rainfall value based on the low r^2 values which were less than 3% in both years. Although there were delays in the greening up of the oil palm plants, the relationship between the variables were linear with positive direction in 2009 and negative direction in 2007. The differences in the direction were attributed to longer lag period in 2007 and shorter lag period in 2009 following from the differences in the amount of the average monthly rainfall received.

In 2007 and 2009, the dry period where the average monthly rainfall is below 100 mm occurred for one month in Febuary and January respectively. These short dry period could explain the small differences in the length of growing season in both years. The start of growing season for 2007 and 2009 begun on the 9 Julian day. It is interesting to note that the EVI values continued to rise into Febuary and March even though the total amount of rainfall received in some of the early months were low. One of the explanation could be due to the effects of time-lag between the availability of rain water and the vegetation phenological response where oil palm plants takes time to show response to water uptakes. Therefore it can be seen that the oil palm phenology values continues to rise even through the months where rainfall is at minimal. For example in 2007, the average monthly rainfall for Febuary and March were between 100 and 200 mm but the EVI values keep climbing before peaking in March. The same situation happens in 2009 where the average rainfall for January and Febuary were between less than 100 to slightly over 100 mm but the EVI values keeps climbing before peaking in March. In both years, heavy rainfall occurred in the preceding months, with year 2007 recorded 603.4mm in December of 2006 and 461 mm rainfall in January whereas December 2008 recorded 207.8 mm of rainfall. It is believed that the heavy rainfall replenished the soil with plenty of soil moisture which fuelled the continuous raise of EVI values for the next couple of months with low rainfall. The end of growing season for the oil palm plants started in line with the decreasing EVI values on 217 Julian day in 2007 and 185 Julian day in 2009 (Figure 3) .

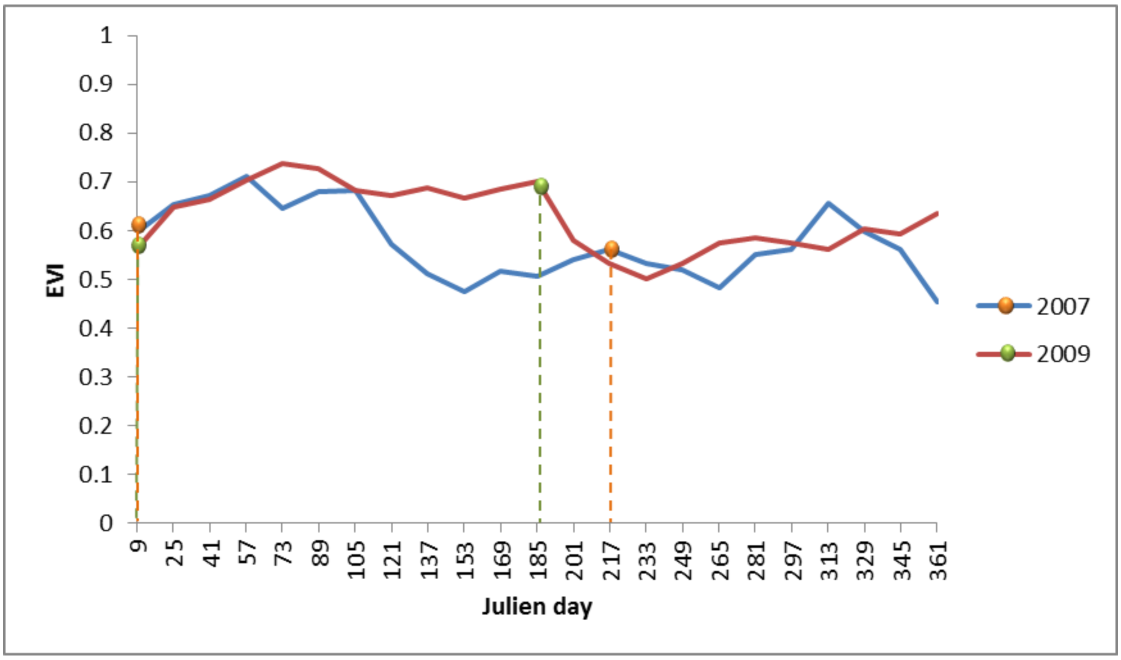


Figure 3 Phenological metrics of oil palm between 2007 and 2009.

Conclusion

In this research the initial results showed differences in response patterns of oil palm towards average monthly rainfall throughout 2007 and 2009. Effect of time-lag period on vegetation's greenness was detected, especially after heavy rain period in both years which affects the correlation values between the average monthly rainfall and EVI. The length of growing season for oil palms in both year showed a difference of 32 days longer in 2007 compared to 2009 which shows that oil palm plants were responsive and sensitive to changes in quantity of available moisture. A longer terms dataset will provide a better understanding of the climate change effects on the phenological response of oil palm which will inevitably impacting the socio-economic aspects of oil palm growers.

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